CHEMICAL COMPOSITION OF DIGESTATE

Juris Priekulis, Elita Aplocina, Armins Laurs
Latvia University of Agriculture
juris.priekulis@llu.lv, elita.aplocina@llu.lv, armins.laurs@promedia.lv

Abstract. Since 2009 39 biogas production stations have been built in Latvia where livestock manure, corn silage and other kinds of biomass are used as raw materials. Therefore, on farms a new kind of soil fertilization is available – digestate produced in biogas production equipment. To compare usefulness of manure and digestate for the needs of soil fertilization 21 biogas production stations were traced, the used manure and digestate samples were taken and chemical analyses of these samples were performed. The research results show that in biogas production stations different kinds of biomass are used as in each of them different raw material components and different proportion of these components are used. Digestate is of greater value if for production of biogas mainly pig or poultry manure is used. In this case in the processed biomass or digestate the amount of N is approximately two times and the amount of P is 1.3 times bigger in comparison to usage of cattle manure. If manure and the produced digestate are compared, in the group of the stations where mainly cattle manure is used, the amount of N in the produced digestate is bigger than in the manure used for its production, but in the group of the stations where mainly pig manure is used – less than in the used liquid manure. It is related to the proportion of the biogas production raw material components and the amount of N contained in them.

Keywords: production of biogas, manure, digestate, chemical composition.

Introduction

The first biogas production station in Latvia was installed and started to work in 1983 in the village Jumprava, Lielvarde region. It was built in the territory of a large pig farm [1] and there liquid manure obtained on this farm was processed. But this biogas production station was of experimental type and soon it stopped to work.

The first up to date biogas production station was built in 2009 on the Training and Research farm "Vecauce" at the Latvia University of Agriculture (LLU). Today, according to the unpublished data of the Latvian Rural Support Service there are already 39 such biogas production stations on Latvian farms and their number continues to grow. Besides, they use not only manure but also other kinds of biomass: corn silage, water sewage treatment plant slime, grain refuse etc.

The effectual Regulations of the Cabinet of Ministers No. 268 [2] state that at every biogas production station at least 30 % of the total used biomass should be manure. Therefore, these stations are built mainly at large livestock farms. The produced biogas is used in co-generation plants to produce electric energy and heat (in form of hot water), but the processed biomass containing manure is used for fertilization of soil. Because of that now on farms a new kind of soil fertilization is available – biomass processed in biogas production equipment or digestate.

According to the data in literature [3] digestate compared to manure has several advantages, but the most important is the fact that it does not cause smell and emissions of undesirable gases in the surrounding environment. Besides, the plant nutrition substances contained in digestate have transformed into a form that is more easily accumulated by plants.

Nevertheless, the composition of digestate is variable as it depends on the kind of the raw materials and the technological process. For instance, it has been stated [3] that pig farm manure digestate dry matter contains 2.9-5.3 % of organic matter, 0.2-1.2 % of total nitrogen, 0.1-0.4 % of phosphorus. But in literature there is not more detailed information given on the influence of biomass used in practice on the chemical composition of digestate. The aim of our research was to state the main kinds of raw materials used in Latvia for production of biogas, to identify the chemical composition of the obtained digestate and its relation to the used biomass.

Materials and methods

Information on the number of biogas stations built in Latvia, their location and energetic power was obtained from the data of the Latvian Biogas Association. In turn, information on the approximate kind of manure used in these stations was obtained from unpublished data of the Latvian Rural Support Service.

To specify the composition of the biomass used in Latvia and the chemical composition of the produced digestate it was necessary to visit the biogas stations. The research was performed within the framework of the contract No. 2014/94 [4] and with the finances allotted for the contract it was possible to trace 21 biogas production stations, i.e. approximately a half of all the biogas production stations built in the country. Selecting the stations for the research the following considerations were taken.

1. Biogas production stations are built at large farms of livestock as it reduces the transport costs of raw materials. Therefore, the chemical composition of the produced digestate is not influenced by the region of the biogas production station location and the stations located in the central part of Latvia can be selected for the research.
2. According to the data of the Latvian Rural Support Service for production of biogas cattle, pig and poultry manure is used. Due to this the biogas production stations included in the research can be divided in three separate groups according to the kind of manure.
3. According to the data of the Latvian Rural Support Service in 2014 from all biogas stations working in Latvia in 24 stations cattle manure was used, in 10 stations – pig manure and only in 5 stations – poultry manure. So, usage of poultry manure is not widely spread. Besides, in the recent years the usage of this manure continues to decrease as the biogas producers stated that it contains small stones and sand that accumulate in the lower part of the bioreactor causing gradual silting of the reactor.

Taking into account these considerations the following number of biogas production stations was included in the research:

- group 1 – biogas production stations where mainly cattle manure is used (11 stations);
- group 2 – biogas production stations where mainly pig liquid manure is used (8 stations);
- group 3 – biogas production stations where mainly poultry manure is used (2 stations).

Visiting the biogas production stations the following information was gathered:

- kinds of the used biomass, the consumed amount per day;
- length and conditions of manure storage (if it is brought and not at once used for production of biogas);
- kind and length of storage of digestate and its procession products (remnants, digestate juice) as well as their possible usage in the production of biogas (for instance, for liquidizing of the biomas for processing).

At every visited biogas production station samples of manure and digestate were taken. The manure sample was taken from the intermediate storage (liquid manure) or a pile (solid litter manure and poultry manure) considering the instructions given in the Regulations No. 669 by the Cabinet of Ministers and in literature about preparation of the collective sample [5; 6]. The digestate sample was taken from the press duct along which digestate is transported into the storage, but in cases when it was not possible – from the storage itself. If in the biogas production station digestate is also dehydrated (separated), then also the dehydrated digestate sample was taken.

The manure samples were analyzed in an accredited laboratory „Vides audits" Ltd. In the analyses the following parameters were determined: the amounts of dry matter and organic matter, pH level, total amount of nitrogen and ammonium nitrogen, potassium (K_2O), and phosphorus (P_2O_5) in accordance with the Regulations of the Cabinet of Ministers No. 506 [7].

Using the results of the analyses data selection could be made for which the statistic indicators were calculated [8, 9]: average value, standard error and relative average standard error as well as it was possible to determine the obtained representation of the results. Also marginal deviations $\Delta_{\bar{x}}$ of some data selections were determined using the following formula for this purpose:

$$\Delta_{\bar{x}} = s_{\bar{x}} \cdot t, \quad (1)$$

where $s_{\bar{x}}$ – arithmetic average standard error of the selection;
t – coefficient of probability that is read from the Stjudent table with 90 % credibility.

Summarizing the research results the main attention was paid to the changes of the amount of nitrogen in the process of biogas production, i.e. in the raw biomass (before processing) and in the produced digestate as it in comparison to potassium and phosphorus can be emitted in the environment.

Results and discussion

Tracing the biogas production stations it was stated that only in two stations one kind of biomass was used: in one – pig liquid manure, but in the other – poultry manure. In all the other stations biomass of several components was used, but most often – manure as well as corn silage.

For instance, in the group of stations where mainly cattle manure is used, farm manure comprised approximately 50 % of the total amount of biomass (calculating according to the weight), but corn silage – 33 % of the total amount of biomass (Table 1). Besides, at every biogas production station different percentual proportion of the biomass components was used.

Total information on the composition of biomass used in the biogas production stations is summarized in Table 1.

Table 1

Number of the biogas production stations included in the research and biomass used in the stations

Indicators	Number of biogas production stations and cases of usage of the corresponding biomass and average percentual amount of biomass *		
	Stations of Group 1	**Stations of Group 2**	**Stations of Group 3**
Number of stations included in the research	*11*	*8*	*2*
Cattle liquid manure	10 /45.5 %	-	1 /5.0 %
Cattle solid manure	5 /5.5 %	1 /2.5 %	-
Pig liquid manure	-	8 /68.0 %	-
Poultry manure	3 /1.0 %	-	2 /62.5 %
Corn silage	10 /33.0 %	5 /20.4 %	1 /32.5 %
Poor quality grain, siftings	2 /3.5 %	4 /3.0 %	-
Whey	1 /0.5 %	-	-
Poor quality potatoes	1 /0.5 %	-	-
Water sewage treatment plant slime	1 /1.0 %	-	-
Digestate or its separated juice*	3 /7.0 %	2 /6.0 %	-
Biomass of another kind	3 /2.5 %	1 /0.1 %	-

*in the numerator – number of cases; in the denominator – percentual proportion

The results of the chemical analyses and their dispersion indicators of the produced digestate at every group of the stations can be seen in Table 2.

According to the conditions of the mathematical statistics [8; 9] the research results are enough reasonable as the average standard error does not exceed 8 %. Therefore, a conclusion can be drawn that the obtained information on the digestate dry matter content, pH value, amount of organic matter and potassium is in compliance with the requirements. In turn, the research in the amount of nitrogen and phosphorus is only approximate. It is due to the large variety of biomass that is used for production of biogas.

As it is shown in the table, the largest amount of nitrogen (total as well as in the form of ammonium) has been obtained from the stations where mainly pig and poultry manure is used. In that case it is approximately two times higher than if mainly cattle farm manure is used as biomass. Digestate containing a large proportion of poultry manure is especially useful as it contains higher amount of phosphorus and potassium. If, for instance, in digestate produced in the Group 1 stations

(using mainly cattle manure) the average amount of phosphorus was 2,68 % (in dry matter), then in the stations of Group 2 (using mainly pig manure) – 3,57 %, i.e. about one and a half times more, but in the stations of Group 3 (using mainly poultry manure) – approximately 6,0 %, i.e. about even two times more.

Table 2

Results of digestate chemical analyses

Indicators	Average arithmetic value with marginal deviation, %	Average standard error, $s_{\bar{X}p}$, %	Average relative standard error, $s_{\bar{X}p}$, %
Group 1 stations (mainly cattle manure is used)			
Content of dry matter	7.28 ± 0.61	0.34	4.7
pH value	7.65 ± 0.15	0.085	1.1
Amount of organic matter, % of dry matter	75.5 ± 2.2	1.21	1.6
Total amount of N, % of dry matter	3.51 ± 0.74	0.54	14.4
ammonium N, % of dry matter	2.82 ± 0.49	0.27	9.6
Phosphorus P_2O_5, % of dry matter	2.68 ± 0.58	0.32	11.9
Potassium K_2O, % of dry matter	5.15 ± 0.49	0.24	4.6
Group 2 stations (mainly pig liquid manure is used)			
Content of dry matter	6.26 ± 2.01	1.09	17.4
pH value	8.04 ± 0.11	0.09	0.7
Amount of organic matter, % of dry matter	72.0 ± 5.1	2.67	3.4
Total amount of N, % of dry matter	7.61 ± 1.59	0.84	11.0
ammonium N, % of dry matter	5.03 ± 2.29	1.21	24.0
Phosphorus P_2O_5, % of dry matter	3.57 ± 1.07	0.57	15.9
Potassium K_2O, % of dry matter	5.03 ± 1.04	0.56	11.2
Group 3 stations (mainly poultry manure is used) *			
Content of dry matter	8.3 and 9.4		
pH value	8.23 and 8.25		
Amount of organic matter, % of dry matter	68 and 63		
Total amount of N, % of dry matter	7.3 and 5.4	-	-
ammonium N, % of dry matter	7.0 and 5.0		
Phosphorus P_2O_5, % of dry matter	6.9 and 5.5		
Potassium K_2O, % of dry matter	5.7 and 6.6		

*In this group there are only two stations, therefore the standard errors were not calculated

Besides, digestate has especially high amount of nitrogen (it reaches 8-12 %) if only pig liquid manure is used as biomass or it is supplemented with grain processing products of low quality: bran, siftings etc. But it becomes very low (on the level of 1-2 %) if digestate or its separated juice is added to the raw biomass (for liquidizing of raw biomass).

Comparison of farm manure as well as digestate according to the amount of NPK in them can be seen in Figure 1.

It can be concluded from the figure that in the stations of Group 1 where mainly cattle manure is used, the amount of NPK in digestate is approximately two times bigger than in manure itself. It is due to the influence of the other raw materials for production of biogas as cattle manure comprised only a half of the total amount of raw materials used for production of biogas (see Table 1). Another situation can be observed in the biogas production stations of Group 2 where mainly pig liquid manure is used (Figure 2).

In this case, pig liquid manure comprises 68 % of the total biomass (Table 1). Therefore, it to a large extent determines the chemical composition of digestate and influences the amount of nitrogen as well as phosphorus in it positively.

A different amount of N was stated in raw digestate and its juices. After pressing the juice the amount of dry matter increases up to 25-29 % and it can be stored in piles, but the amount of N in juices is already 2.5-3.5 times less than in the freshly produced digestate.

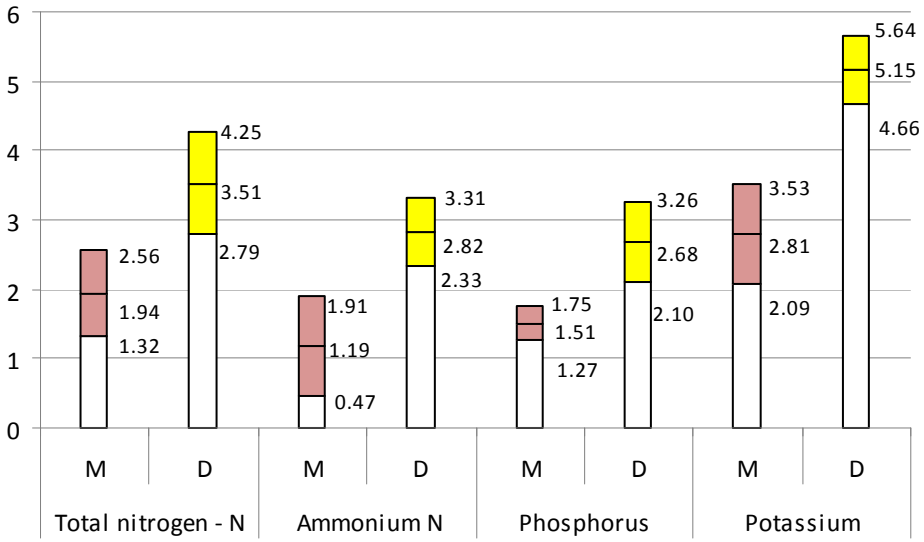

Fig. 1. **Comparison of the chemical composition of cattle manure and the processed digestate, % of dry matter showing the marginal values and average values:** M – cattle manure used for production of biogas; D – produced digestate

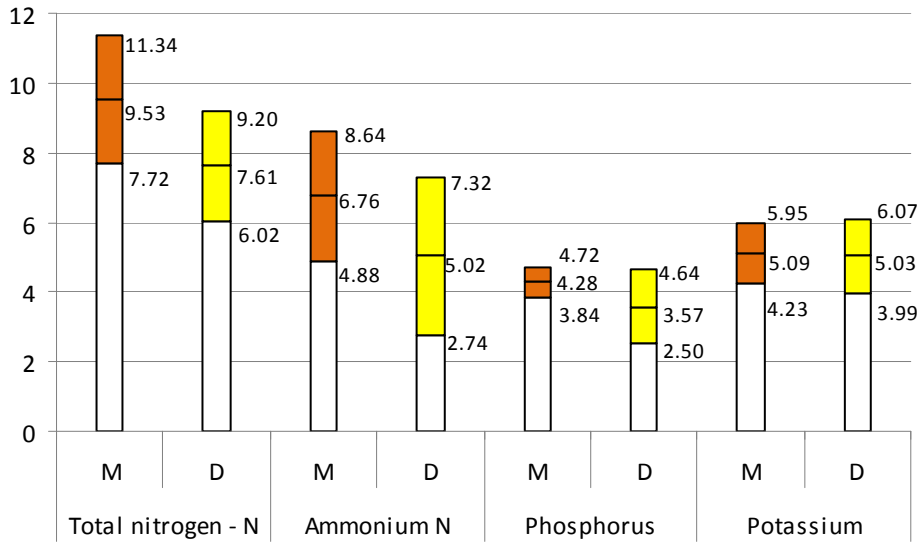

Fig. 2. **Comparison of the chemical composition of pig liquid manure and the processed digestate, % of dry matter showing the marginal values and average values:** M – pig liquid manure used for production of biogas; D – produced digestate

Conclusions

1. At every biogas production station different kinds of biomass are produced with different components of raw materials and the proportion of these components.
2. All biogas production stations can be relatively divided in three big groups: stations where mainly cattle farm manure is used, stations where mainly pig liquid manure is used and stations where mainly poultry manure is used. Still, poultry manure is used only in few stations as it has been stated in practice that they contain sand and small stones that cause silting of the biogas reactors.

3. If for production of biogas mainly pig or poultry manure is used, then compared to the usage of cattle manure there is approximately two times bigger amount of N and 1.3 times bigger amount of P in the processed biomass or digestate.
4. In digestate produced in the stations where mainly cattle farm manure is used the amount of N is bigger than in the farm manure that has been used for its production, but in digestate produced from pig manure – less than in the manure. It is due to the amount of the proportion of the components and their chemical composition in raw biomass.
5. Separating the juice the content of digestate dry matter increases up to 25-29 % and it can be stored in a pile but the amount of N in the juices is 2.5-3.5 times less than in raw digestate.

Acknowledgements

This research was done on financial support of the project "Agricultural sector GHG emissions calculation methods and data analysis with the modelling tool development, integrating climate change".

References

1. Dubrovskis V., Viesturs U. Agricultural Waste Methane Fermentation. R. :Zinātne, 1988. 240 p.
2. Regulations No.268 of the Cabinet of Ministers. Procedure of the state and the European Union grant allocation for the activity „Support for Establishing and Development of Enterprises (including diversification of activities not related to agriculture)". In force since March 16, 2010.
3. Dubrovskis V., Adamovičs V. Horizons of Bioenergetics. Monograph. Jelgava, LLU, 2012, 352 p.
4. Contract No.2014/94. Research "Agricultural sector GHG emissions calculation methods and data analysis with the modelling tool development, integrating climate change". Registered on 18.09.2014.
5. Regulations No. 669 of the Cabinet of Ministers. Procedure of fertiliser and plant nutrition substrate control sample collection and preparation. In force since October 28, 2014.
6. Peters J. Recommended Methods of Manure Analysis (A3769). University of Wisconsin – Extension, 2003, 58 p. [online][08.12.2015] Available at: http://learningstore.uwex.edu/Recommended-Methods-of-Manure-Analysis-P106.aspx
7. Regulations No. 506 of the Cabinet of Ministers. Regulations on fertilizer and substrate identification, quality compliance evaluation and trade. In force since September 15, 2015.
8. Arhipova I., Bāliņa S. (2003) Statistics in Economics. R.Datorzinību Centrs. 351 p. (In Latvian)
9. Brāzma N., Brigmane A., Krastiņš A., Rāts J. (1970) Higher Mathematics. R. Zvaigzne. 545 p. (In Latvian)